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ABSTRACT

This fifth in a series of six modules for a course titled Civil/Structural Inspection introduces various test methods and equipment associated with concrete testing and provides a practical background for the actual inspection of the associated construction activities. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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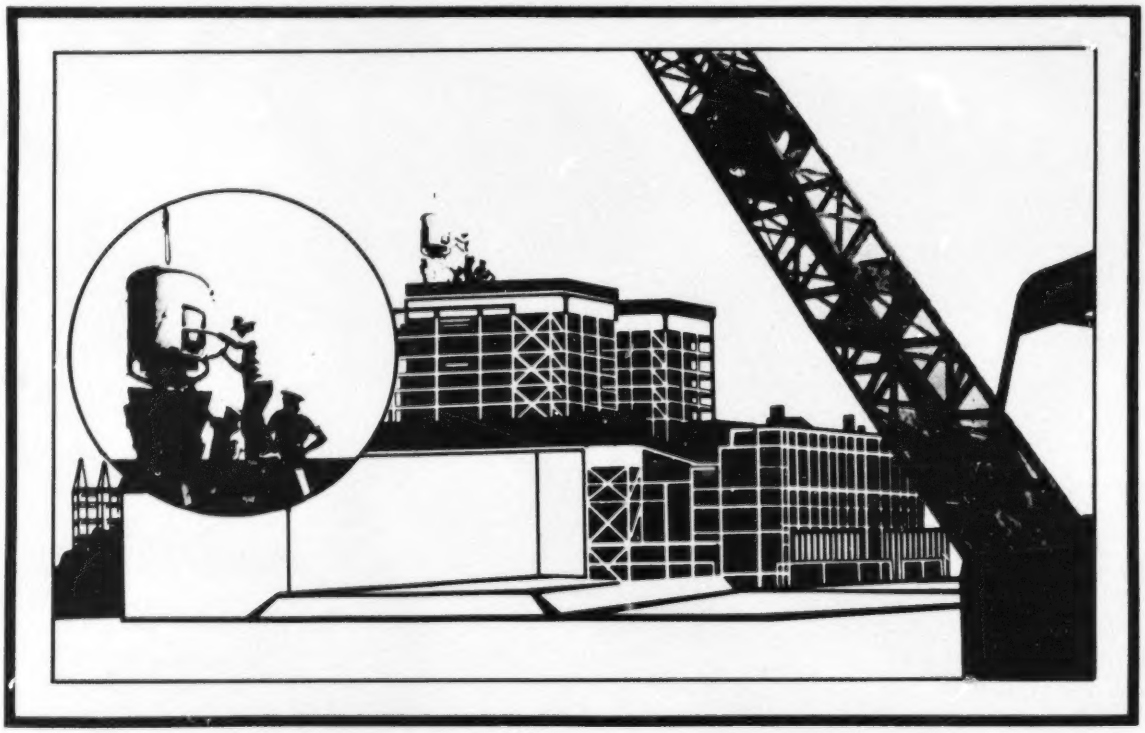
# NUCLEAR TECHNOLOGY

## COURSE 29 CIVIL/STRUCTURAL INSPECTION

### MODULE 29-5 Concrete Testing and Inspection



CE 024 275

GENERAL PHYSICS CORPORATION
Columbia , Maryland

# COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

| | |
|---|---|
| Module 29-1 | Inspection of Construction Operations |
| Module 29-2 | Structural Steel Materials, Installation, and Inspection |
| Module 29-3 | Concrete Materials |
| Module 29-4 | Concrete Preparation, Production, Placement and Finishing |
| Module 29-5 | Concrete Testing and Inspection |
| Module 29-6 | Prestressed Concrete Materials, Fabrication, and Inspection |

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This module was prepared for General Physics Corporation by Richard Groseclose, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

# INTRODUCTION

Concrete testing and inspection generally includes the following:

- Control of batching and proportioning; tests of consistency, air content and unit weight of concrete.
- Continual inspection of the mixing, conveying, placing, consolidation, finishing and curing of concrete.
- Sampling and preparation of concrete specimens for laboratory testing.
- Observation of contractor's plant and equipment, working conditions, weather, and other items affecting the concrete.
- Witnessing of laboratory testing of concrete specimens.
- Preparation of records and reports.

Concrete is sampled and tested for two reasons: (1) to determine whether or not the characteristics of the batch conform with the specification requirements, and (2) to check for variations in characteristics within the batch as a measure of uniformity.

The inspection of concreting operations is performed to assure that the work is performed in accordance with the plans and specifications, and with good practice.

The QA/QC Technician may be trained and qualified to perform any or all of these inspection activities. This module is designed to introduce the various test methods and equipment associated with concrete testing, and to provide a practical background for the actual inspection of the associated construction activities.

# MODULE PREREQUISITES

The student/trainee should complete Modules 29-1, 29-3 and 29-4 before proceeding with this module.

# OBJECTIVES

Upon completion of this module, the student/trainee should be able to perform the following:

1. Demonstrate a knowledge of concrete testing techniques and equipment, including sampling, tests for concrete consistency, air content compressive strength, and analysis of test data by completing written exercises on:
   (a) sampling
   (b) applicable standards
   (c) slump testing
   (d) ball penetration tests
   (e) air content tests
   (f) cylinder molding
   (g) compressive strength testing
   (h) data analysis, including average strength, standard deviation, and coefficient of variation

2. Given the statistics on typical batcher equipment, describe the procedure for calibrating the weight scale.

3. Complete written exercises on concrete batching operations.

4. Complete written exercises on concrete mixing and transportation, which require the following:
   (a) listing factors which affect mixing thoroughness
   (b) calculating maximum recommended concrete capacity for a specific size truck-mixer drum
   (c) calculating the expected air content of a concrete batch after a given amount of mixing
   (d) describing the method of checking batch unformity

5. Given a typical concrete specification, devise a check list of items that should be monitored, tested and inspected during a concrete placement operation.

# SUBJECT MATTER

## CODES AND STANDARDS

Many codes and standards are applicable and must be followed in nuclear plant construction operations. Plant specifications and drawings are prepared to cover all plant areas and construction activities, and incorporate or invoke the applicable standards. The standards most used which cover concreting operations are published by the ASTM, American Society for Testing and Materials, and the ACI, the American Concrete Institute. Some of these standards were introduced and listed in Moduel 29-4.

Rather than describing specific standards at this point, they will be discussed at appropriate times throughout the balance of this module.

## CONCRETE TESTING TECHNIQUES AND EQUIPMENT

### Sampling of Fresh Concrete

In order for test results to accurately reflect the quality of the concrete, samples must be representative and tests made properly. Normally, an inspector takes samples of concrete for tests, molds the specimens in cylindrical molds, cures the specimens up to the time for shipment or test; and either ships them to a laboratory for tests, or tests them in the field as required. Sampling is performed in accordance with ASTM Standard C 172 "Methods of Sampling Fresh Concrete" as the concrete is delivered from the final mixer. This may be from a stationary mixer at a mixing plant (central mixer) or from a truck mixer (transit mixer) as it prepares to discharge concrete at the placement location.

Securing representative concrete samples requires a combination of knowledge, skill and the exercise of informed

judgement. Samples which are carlessly taken will not represent the batch and cannot yield significant results from the subsequent tests.

ASTM C 172 outlines procedures for taking the samples. Samples taken for acceptance tests must consist of portions from two or more points in the batch. The portions may not be taken from the beginning or the end of a batch, and should be secured by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream completely into a container. The individual samples, or portions, are transported to the place where the fresh concrete tests are to be made or where test specimens are to be molded. They are then combined and remixed with a shovel the minimum amount necessary to ensure uniformity. Tests for slump or air content should be started within 5 minutes after sampling is completed, and finished as expeditiously as possible. Specimens for strength tests should be molded within 15 minutes after mixing the composite sample. Before testing or molding, samples should be protected from the sun, wind, and other sources of evaporation, and from contamination.

In the records which are maintained for the concrete samples, the location in the structure of the batch of concrete from which the sample is taken should be noted, together with pertinent data regarding the appearance of the mix, and temperatures of the air and the concrete.

Samples should be taken at random from any batch of concrete being placed during the run. Samples should not be taken at regular intervals, nor with any prolonged preparation that can be observed by or reported to the batching or mixing operator.

Specimens molded for strength tests should, under no circumstances, be moved or disturbed after molding, especially for the first 24 hours. Any such action may cause a deterioration in resulting strength.

Samples are also taken periodically during a pour to check concrete uniformity. The samples are secured in the same way as the increments for acceptance-test samples, but are tested separately (not combined) to reveal variations within each batch of concrete. Tests for checking uniformity may include slump, air content, unit weight, compressive strength and other properties.

## Concrete Specifications

ASTM Standard C 94, "Ready-Mixed Concrete", is used by many constructors and architect-engineers as a basis for developing concrete specifications, and as a basis for purchase requirements when the concrete is purchased from subcontractors. The C 94 standard provided limits for controlling such variables as slump, air content, measurement of materials, water content, batching plant operation, mixing speeds and times, delivery methods and equipment, strength and uniformity. The concrete inspector should be thoroughly familiar with the applicable concrete specifications, and all required tests.

## Slump Test

The slump test is generally considered the most useful single basis for concrete acceptance. It measured the consistency or wetness of the batch, and provides an indication of its water content. If the slump is maintained within prescribed tolerances, the mixing water content will be correct for a properly designed batch containing accurately weighed component materials. The slump, then, provides a reliable check on the water-cement ratio of the batch and the probable strength, with one exception: the slump test is not valid for concrete which has been mixed for long periods or held for long periods after mixing and to which water has been added to restore lost slump. Such practices

are detrimental to concrete quality and strength even when the slump is maintained at the specified level.

The procedure and equipment is described in ASTM Standard C 143, "Slump of Portland Cement Concrete". The equipment required for the test consists only of a metal, conical shaped mold as illustrated in Figure 29-5-1, which is placed on a flat, level non-absorbent surface such as a metal plate.

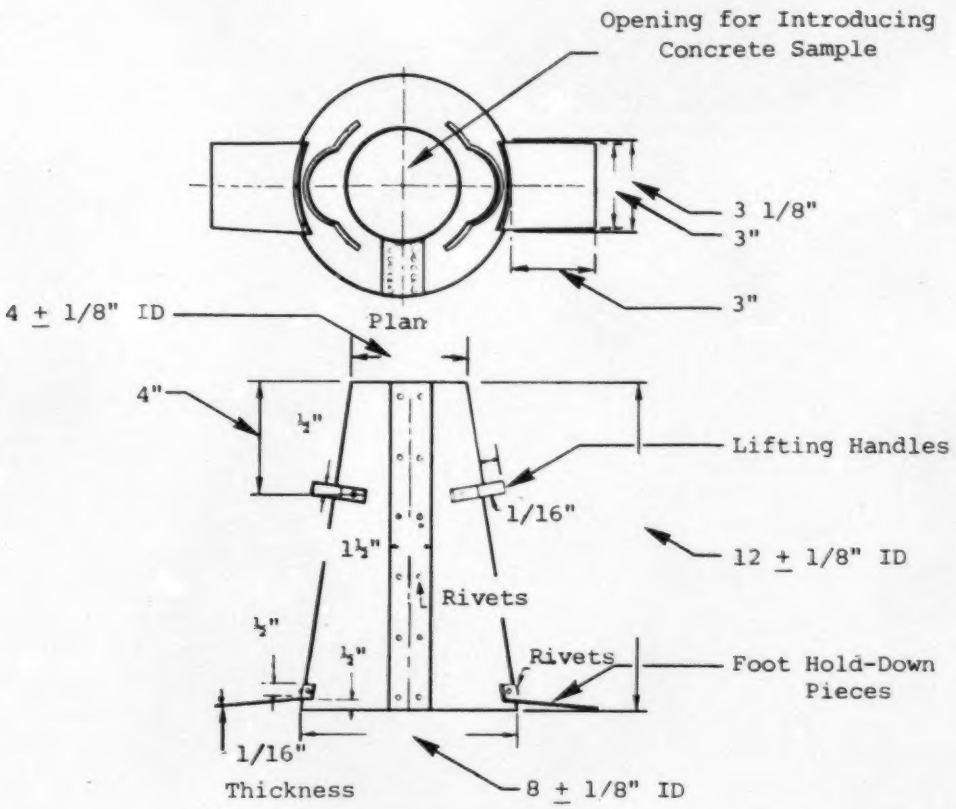



Figure 29-5-1 Slump Test Mold

Before the test, the mold is dampened with water and placed on a flat surface which also has been dampened. The test operator (concrete inspector) holds the mold in place by standing on the foot pieces, and introduces the concrete sample into the opening in the top, filling the mold in three layers of about equal volume. Each layer is "rodded" 25 times with a 5/8" diameter rounded-tip steel rod, with strokes which just penetrate the underlying layer and which are evenly distributed over the cross-section of the mold.

In placing the third and final layer, the mold should be filled to overflowing. After it has been rodded, the top of the concrete is struck off with the tamping rod so that the mold is exactly filled. The mold is then carefully removed by lifting it slowly in a vertical direction in such a manner as to permit symmetrical settlement. The entire operation of filling and removing the mold should be performed in 1 to 1-1/2 minutes. The height of the mold is then compared to the height of the settled concrete; the difference in heights, measured at the vertical axis and the top surface of each is defined as the slump. Careful removal of the slump cone is important, as any lateral motion, vibration or other disturbance usually results in a higher apparent slump value.

Tolerances and acceptance criteria for slump tests are specified in ASTM Standard C 94. C 94 provides that when the specified slump is 3 inches or less, the tolerance shall be $\pm$ 1/2 inch; when the specified slump is greater than 3 inches, the tolerance shall be $\pm$ 1 inch. If the slump falls outside of the specified limits, a second test or check test must be made. The concrete is considered unacceptable only after the failure of the second test.

Ball Penetration Test

The ball penetration test provides simple rapid check of concrete consistency. The test, as covered by ASTM Standard C 360, consists of observing the penetration of a 6" diameter, 30 pound metal ball into the surface of a sample of fresh concrete. The penetration normally measured about one-half the slump, but does not necessarily hold for all conditions of test, and is not directly proportional to the slump. It has the advantage of not requiring the molding of a specimen, and of permitting the testing of fresh concrete in wheelbarrow or other container, or even in the forms. When used by an experienced inspector, the ball penetration test can provide a reasonably accurate approximation of the slump. The test is not used quantitatively for acceptance or rejection of the concrete, but for routine checking of consistency for control purposes. Figure 29-5-2 illustrates the Ball Penetration Test Apparatus.

Air Content Tests

The amount of entrained air in concrete has a significant effect on strength and workability. Too much air detracts from strength without a compensating improvement in durability, and too little will result in poor workability and durability.

The amount of desired entrained air is specified as maximum and minimum percentages in the design mix specification. It is important that the air content is unformly close to the desired amount, batch after batch, and day after day.

Three methods for the determination of air content of fresh concrete have been standardized by the ASTM: the pressure method, and the volumetric method, and the gravimetric method. The gravimetric method is the least accurate,

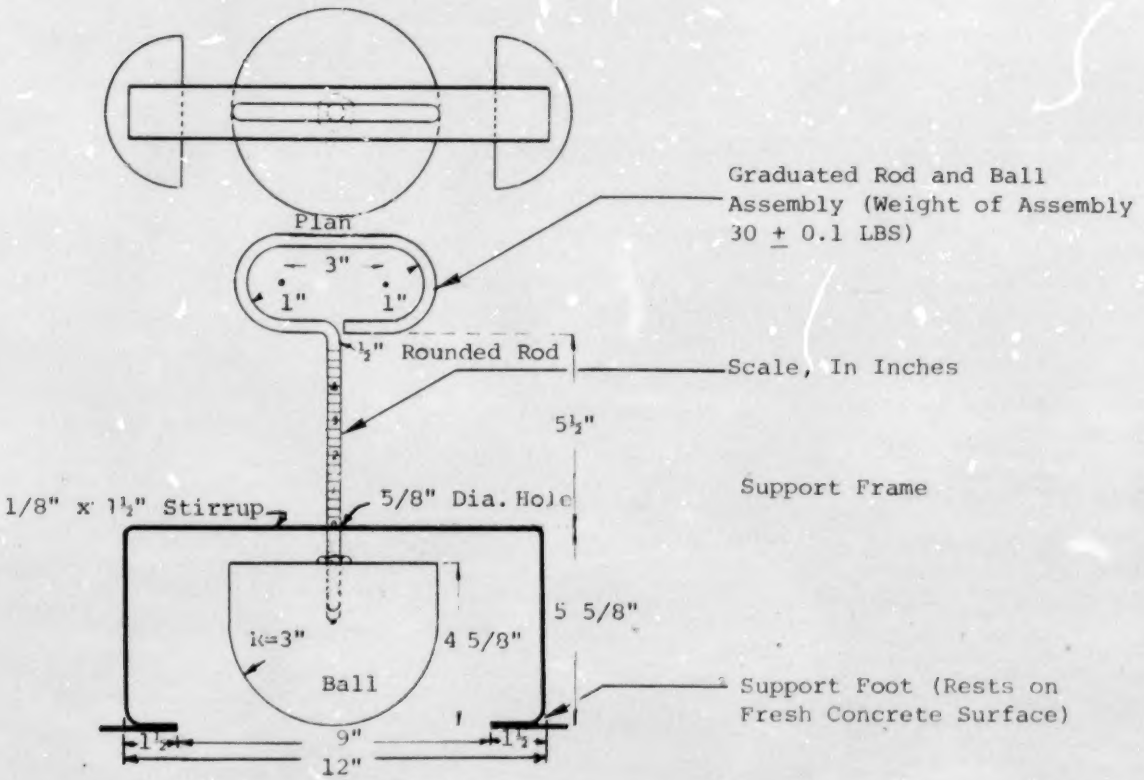



Figure 29-5-2 Ball Penetration Test Apparatus

however, due to unavoidable variations in the proportions of the mix, and will not be described in this module.

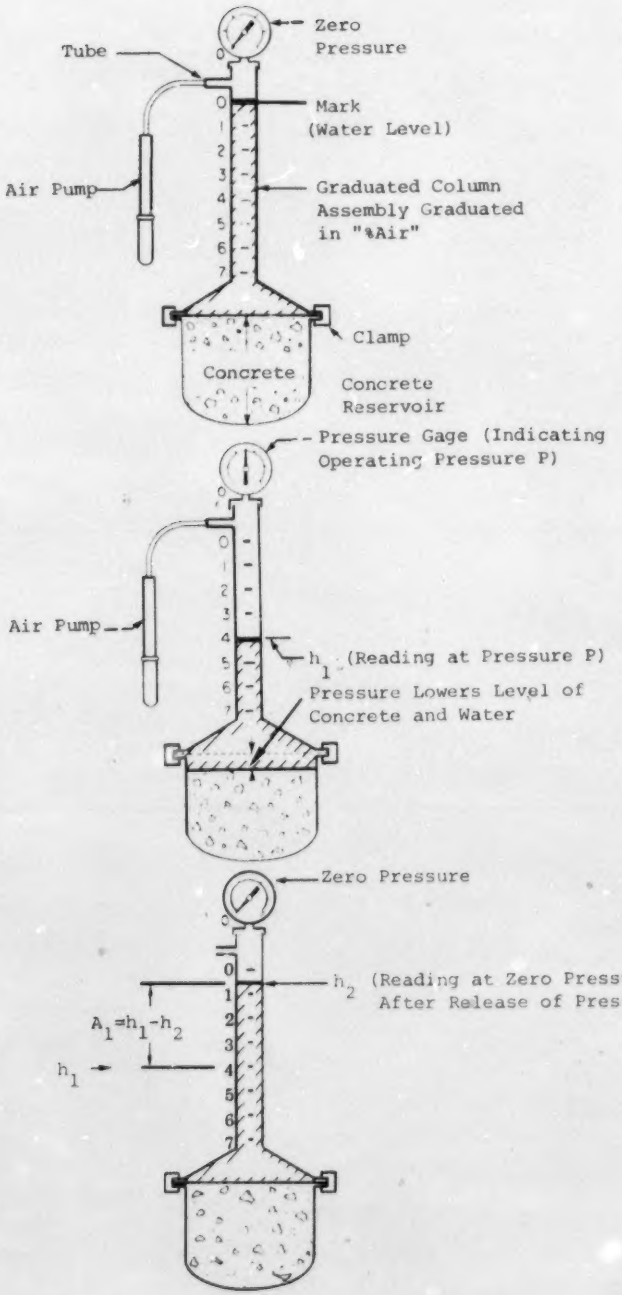
The pressure method, ASTM Standard C231, depends on application of Boyle's Law: the volume of a gas (in this case, the entrained air) varies inversely with the pressure applied to it. The amount by which a known volume of concerete can be compressed when subjected to known pressure is a measure of the air contained within. Basically, the apparatus consists of a special pressure-tight container with accessories, capable of measuring precisely the volume of concrete. ASTM C231, describes two variations of this

apparatus, the Type-A Meter and the Type-B Meter. The Type-A Meter is illustrated, and its operation described in Figure 29-5-3. (Please refer to the following page for Figure 29-5-3.)

The ASTM Type-B Meter provides a direct reading of percent air content on a pressure gage. With this device, as illustrated in Figure 29-5-4, water is introduced with a syringe through Petcock A to cover the concrete sample in the measuring bowl and emerges from Petcock B, while the main air valve is closed. Air is pumped into the air chamber to a predetermined pressure (which indicates as zero percent on the pressure gauge.) The main air valve is then opened, allowing the air to compress the concrete sample in the bowl. The pressure in the air chamber is reduced proportionally, and the apparent percent of air contained in the sample is read directly from the calibrated pressure gage. A correction factor "G" for air contained in the aggregate may be required, and would be determined by testing a sample of aggregate only. The air content of the sample then, $A=A_{apparent}$ -G (aggregate correction factor.)

These pressure type tests are considered adequate for all ordinary types of concrete and mortar, except those made with highly porous aggregates. They are not dependable with most lightweight aggregates.

The volumetric method consists of placing a known volume of concrete in a suitable container known as a "pycnometer", covering it with water, and then rolling, shaking or otherwise stirring the concrete to remove the air. As the water replaces the air in the concrete, the resulting reduction in volume of the concrete-water mixture is equal to the volume of air removed. This method can be used for testing most all concrete and mortar mixtures, and is particularly useful for testing concrete made with porous or lightweight aggregates for which the pressure method does not give reliable




Operation

1. Concrete sample is placed in the reservoir and the surface struck-off even with the rim.
2. Reservoir is attached and sealed to the graduated column assembly.
3. Water is added through the tube, covering the concrete, up to the zero mark.
4. Air pump is attached to the tube.
5. Air pump is operated to increase pressure to specified operating pressure P.
6. Etrained air in concrete is compressed and level of concrete, and water in the graduated column.
7. Water level $h_1$, at pressure P is read and recorded.
8. Pressure P is released, and water level $h_2$ is read and recorded.
9. Apparent air content, $A_1=h_1-h_2$.
10. Aggregate correction factor, $G_1$ is determined by placing only an aggregate sample and water in the meter and repeating the test. $(G=h_{1(ag.)}-h_{2(ag.)})$
11. Air content of concrete, $A=A_1-G$.

Figure 29-5-3 ASMT C231 Type A Air Content Meter and Operation

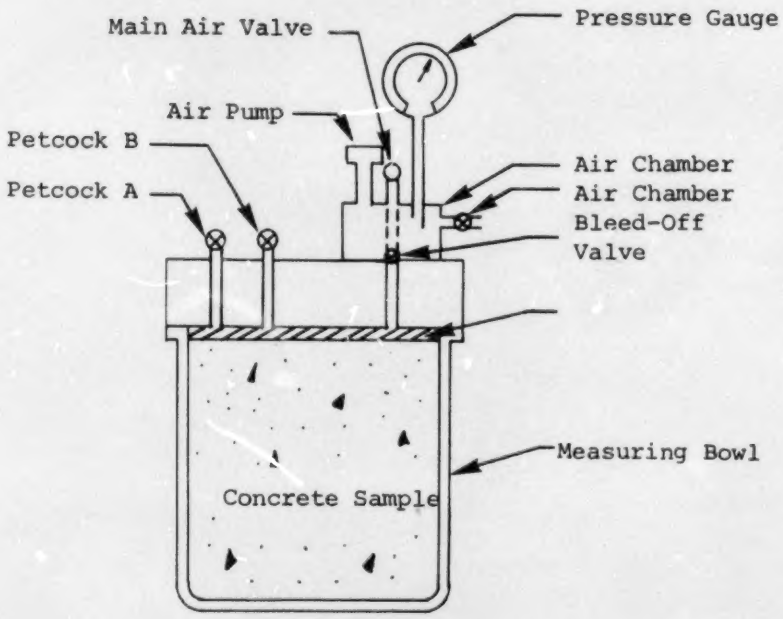



Figure 29-5-4 ASTM Type B Air Content Meter

results. Figure 29-5-5 shows the volumetric type apparatus by the ASTM.

Strength Tests

Fresh concrete samples must be molded into cylindrical test specimens and cured before compressive strength tests are performed. ASTM Standard C 31, "Making and Curing Concrete Compressive and Flexural Strength Test Specimens in the Field", is the standard used throughout the construction industry for preparing such specimens.

The molds generally used are heavily waxed waterproof cardboard tubes, measuring 6" in diameter by 12" high. They may have bottoms or be set on base plates. The molds should be placed on a smooth, firm, level surface for filling and

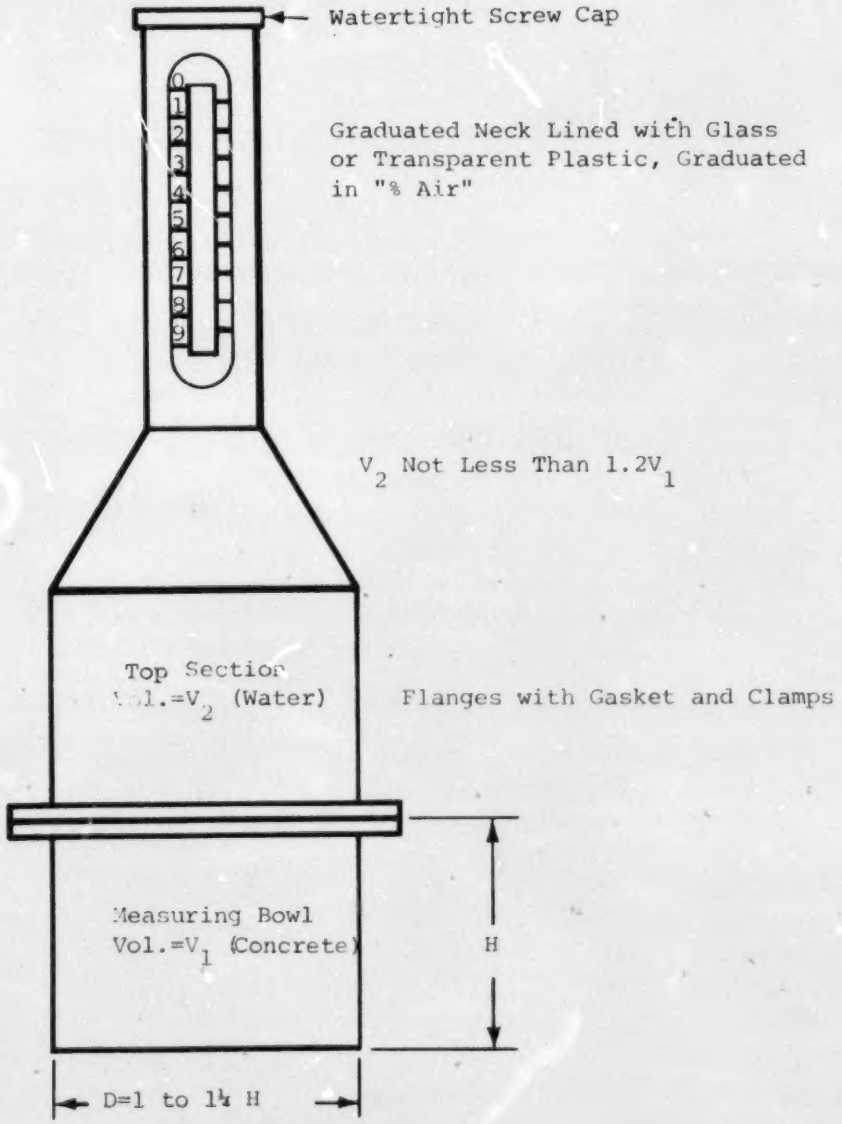

Watertight Screw Cap
Graduated Neck Lined with Glass or Transparent Plastic, Graduated in "% Air"
$V_2$ Not Less Than $1.2V_1$
Top Section Vol.=$V_2$ (Water)
Flanges with Gasket and Clamps
Measuring Bowl Vol.=$V_1$ (Concrete)
H
D=1 to 1¼ H

Figure 29-5-5 ASTM Volumetric Type Air Content Apparatus (Pyconmeter)

cast in the area where they are to be stored for the first 24 hours, protected from vibration, jarring, or other disturbance.

C 31 requires that the molds be filled in three equal layers, and each layer uniformly rodded 25 times with a 5/8" diameter bullet-nosed rod. When rodding the second and third layers, the rod should just break through into the layer beneath. The operator should attempt to add an amount of concrete in the final layer that will exactly fill the mold after compaction (rodding), or leave a slight excess. The specimen is finished by striking off the excess even with the rim of the mold and smoothing the surface with a float or trowel.

After finishing, the molds should be covered to prevent loss of moisture by evaporation, and protected from temperatures below 60°F or above 80°F.

Standard-cured specimens indicate the potential strength of the concrete; they are made to check the adequacy of mix proportions or as the basis for acceptance of the concrete. Field-cured specimens indicate the degree to which strength is affected by the actual conditions of temperature and moisture; they are used to determine when a structure may be put into service.

C 31, requires that standard-curved cylinders be stored in a moist condition at 73.4 ± 3°F until the moment of test. The moist curing must begin when the cylinders are removed from their molds at the end of 20 ± 4 hours from the time they were cast. The specimens may not be exposed to a stream of running water, but some free water must be maintained on their surfaces at all times.

Cylinders are also removed from the molds after 24 hours for field-curing. Field-curing means that the cylinders should be stored in the structure as near to the point of sampling (or placement) as possible, and should receive the

same protection from the elements on all surfaces as is given to the portions of the structure which they represent. The cylinders should be kept in the field at least three-fourths of the scheduled period of curing, then sent to the laboratory. They may be stored at laboratory temperature until 24 $\pm$ 4 hours immediately before time of testing, when they must be immersed in lime water until the time of testing to ensure uniform moisture condition from specimen to specimen.

It should be emphasized that careful standard treatment of all test specimens is absolutely necessary to obtain true, representative test results.

Concrete test cylinders must have bottom and top surfaces which are parallel and at right angles to the axis of the cylinder, as required by the C 31 standard. The surfaces should also provide uniform distribution of the compressive pressure for a valid test. To meet these requirements, the ends of the cylinders are usually capped before testing with neat cement paste, high-strength gypsum plaster, alumina cement, or sulphurous mixtures. The basic requirements for the caps is that the cap must not flow or fracture when the specimen is tested.

Sulphur caps are widely used, and harden satisfactorily for testing within 2 hours. The mixture is heated and melted in thermostatically controlled heating pots, and poured in shallow molds of the same diameter as the test cylinder. The concrete cylinder end is set in the molten material and clamped in place until the material solidifies. The capped cylinder is removed from the mold, inverted, and the other end capped in the same manner.

Strength tests are performed in accordance with ASTM Standard C 39, "Method of Test for Compressive Strength of Molded Concrete Cylinders".

The testing machines used must be of sufficient capacity, power operated, and apply the load continuously, rather than

intermittently, and without shock. Most machines currently in use are hydraulic. The test pressure is applied to the end surface of the test cylinder (Diameter - 6 in., Area approximately 28.27 sq. in.) For some concrete mixtures, strengths may exceed 6,000 pounds per square inch (psi). Therefore, the test machine capacity should exceed (28.27 sq. in. x 6,000 psi = 169,620 pounds) approximately 170,000 pounds.

Compression tests should be made as soon as the test specimens are removed from the curing room as practicable. Correct, representative strength values are not obtained if the cylinders dry out partially before being tested.

The test cylinder is mounted on the test machine between spherically-seated bearing blocks. The test is started with continuous pressure loading, and continues until the cylinder fractures, recording the maximum load obtained.

In computing the unit strength of the specimen, the diameter of the cylinder is measured to the nearest 0.01 inch by averaging two diameters at right angles to each other near the center of the length of the specimen. The average area is calculated from the average diameter, and the value is divided into the maximum load recorded in the test to determine the compressive strength.

EXAMPLE:

Cylinder A - Diameter (1) - 5.93"

Diameter (2) - 5.99"

Average Diameter - 5.96"

Area $(\frac{5.96}{2})^2 \times (3.142) = 18.60$ sq. in.

Maximum test load: 79,590 lbs.

Compressive strength: $\frac{79,590 \text{ lbs.}}{18.60 \text{ sq. in.}} = 4,279$ psi (or 4,280 psi)

Cylinder B - Diameter (1) - 6.01"

Diameter (2) - 6.05"

Average Diameter - 6.03"

Area $(\frac{6.03}{2})^2 \times 3.142 = 18.95$ sq. in.

Maximum test load: 80,350 lbs.

Compressive strength: $\frac{80,350 \text{ lbs.}}{18.95} = 4,240$ psi

The calculated compressive strength is rounded off to the nearest 10 psi, and listed in a report for each specimen along with the following information:

- Cylinder identification number
- Diameter (average), in inches
- Cross sectional area, in inches
- Maximum load, in pounds-force
- Type of fracture
- Defects in either specimen or caps
- Moisture condition of specimen
- Age of specimen
- Slump of concrete

The number of specimens prepared and tested depends on the purpose of the tests, the use to be made of the results, and the volume of concrete placed. In most cases, two specimens are prepared and tested, and the results averaged for each single test. Complete reliance, such as for an accept/reject decision, should never be placed on a single specimen.

The magnitude of variations in strength of test specimens depends upon the control of materials, concrete manufacture, and testing. Differences in strength are generally caused by either differences in the strength-producing properties of the concrete, or apparent differences caused by discrepancies in the tests.

Analysis of Compression Test Results

Variations in the strength of concrete must be expected, but concrete of adequate quality can be produced consistently if proper control is maintained, and test results are interpreted properly. Conclusions on strength of concrete should be derived from a pattern of tests from which the characteristics and uniformity of the concrete can be accurately estimated.

ACI Standard 214, "Recommended Practice for Evaluation of Compression Test Results of Field Concrete", presents the statistical methods which are generally used for evaluating strength test results.

Some of the terms used in evaluating the test data are as follows:

(1) Mean (Average), $\bar{X}$ - average strength of all cylinders.

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \ldots + X_n}{n}, \text{ where}$$

$X_1$, $X_2$, $X_3$ ... $X_n$ are the strength results of individual tests, and n is the total number of tests.

(2) Standard Deviation, $\sigma$ - A measure of variability, defined as the square root of the average squared deviations of individual strengths from their Mean.

$$\sigma = \sqrt{\frac{(X_1-\bar{X})^2 + (X_2-\bar{X})^2 + (X_2-\bar{X})^2 + (X_3-\bar{X})^2 + \ldots + (X_n-\bar{X})^2}{n}}$$

(3) Range, R - The difference between the highest and lowest values in a set of data. Range is found by subtracting the lowest strength in any group of tests from the highest strength.

(4) Coefficient of Variation, V - The standard deviation expressed as a percentage of the mean (average strength).

$$V = \frac{\sigma}{\bar{X}} \times 100$$

Table 29-5-1 lists the concrete compressive strength data taken at a field batch plant over a period of a month. This data collected can be used to evaluate the degree of uniformity in producing a particular design-mix concrete. The example which follows shows how this may be done.

Table 29-5-1

Concrete Compressive Strength

| Test No. | 28-Day Strength, psi | | $X_j$, Average Strength | Range, psi | $(\Delta X)^2$ or $(X_j - \bar{X})^2$ |
|---|---|---|---|---|---|
| | Cylinder 1 | Cylinder 2 | | | |
| 1 | 3420 | 3670 | 3545 | 250 | 4,225 |
| 2 | 3330 | 3190 | 3260 | 140 | 48,400 |
| 3 | 4030 | 3920 | 3975 | 110 | 245,025 |
| 4 | 2830 | 3120 | 2975 | 290 | 225,025 |
| 5 | 3810 | 3190 | 3500 | 620 | 400 |
| 6 | 3610 | 3210 | 3410 | 400 | 4,900 |
| 7 | 3560 | 3790 | 3675 | 230 | 38,025 |
| 8 | 3410 | 3500 | 3455 | 90 | 625 |
| 9 | 3490 | 3300 | 3395 | 190 | 7,225 |
| 10 | 3810 | 3500 | 3655 | 310 | 30,625 |
| 11 | 3510 | 3260 | 3385 | 250 | 9,025 |
| 12 | 3800 | 3200 | 3500 | 600 | 400 |
| TOTAL | | | 41,730 | 3,480 | 643,900 |

EXAMPLE:

Using the concrete strength data presented in Table 29-5-1, evaluate the degree of uniformity in producing a particular design mix concrete by calculating the standard deviation of the individual strengths of the cylinders, their average range in strengths and their coefficient of variation. This may be done as follows:

From Table 29-5-1, the total number of tests, n, is:

$$n=12$$

The average strength can be computed using $\Sigma X_j$ = 41,730 psi as shown in Table 29-5-1 for all 12 tests, and therefore the average strength of all cylinders is:

$$\bar{X} = \frac{\Sigma X_j}{n}$$

$$= \frac{41,730}{12} - 3478 \text{ psi (rounded off to 3480 psi)}$$

Next, it is necessary to compute the standard deviation, which is a measure of the variability in the strength of each cylinder:

$$\sigma = \sqrt{\frac{(X_j - \bar{X})^2}{n}}$$

$$= \sqrt{\frac{643,900}{12}}$$

$$= \sqrt{53,658}$$

$$\sigma = 232 \text{ psi}$$

From these data, we can see that the average range, or average difference between the highest and lowest set of data is:

$$\text{Average Range} = \bar{R} = \frac{3480}{12} = 290 \text{ psi}$$

As a result, the coefficient of variation, V, which is the standard deviation expressed as a percentage of the mean can be

computed as:

$$V = \frac{\sigma}{\bar{x}} \times 100\%$$

$$= \frac{232}{3480} \times 100\%$$

$$V = 6.67\%$$

Table 29-5-2 shows the range of coefficients of variation, V, that can normally be expected on controlled projects. The ratings of control are based on experience from a large number of projects, as reported by the ACI, and are presented as a general guide in evaluation of concrete control.

Table 29-5-2

Standards of Concrete Control

| Class of Operation; Overall-Variations: | V, Coefficients of Variation, for Different Control Standards | | | |
|---|---|---|---|---|
| | Excellent | Good | Fair | Poor |
| General Construction | Below 10.0 | 10.0 to 15.0 | 15.0 to 20.0 | Above 20.0 |
| Laboratory Control | Below 5.0 | 5.0 to 7.0 | 7.0 to 10.0 | Above 10.0 |

Core Sampling and Testing

Specimens are frequently cut from the hardened concrete cast in the structure to verify the concrete quality. The specimens may be either beams or cylindrical cores, and are covered in ASTM Standard C 42.

Most sampling is done with the cylindrical core shape. The core specimen is cut with a length about twice its diameter, with a large hollow drill. The size drill is selected to cut a cylinder about 3 times in diameter larger than the nominal size of the coarse aggregate.

Compressive strength tests are performed on the specimens in the same manner as molded cylinders. The ends of the core are either ground smooth or capped so as to present plane surfaces against which the test load is applied. The length and average diameter of the core should be measured to 0.1 in., and the breaking strength calculated in pounds per square inch. Test reports and the analysis of test results is handled in the same manner as for molded cylinder tests.

## CONCRETE BATCH PLANT INSPECTION

The consistent quality and uniformity of concrete begins with accurate batching. Accurate batching is dependent upon: (1) equipment properly maintained in good operating condition, (2) equipment properly calibrated at specified times and frequency, and (3) proper equipment operation and adherence to design mix proportions.

The inspector monitors these activities and provides assurance that these factors are properly controlled. Before batching begins, the equipment should be inspected for such items as : (1) internal cleanliness, freedom from "caked" materials or residue on hopper or chute sides, (2) clean, friction-free working parts, particularly knife edges on weighing devices, (3) loose nuts or other parts, (4) tight weighing containers and closing devices, (5) equipment correctly leveled, and (6) unobstructed view of weighing mechanism to allow observation by batcherman.

The inspector should witness scale and meter calibrations and assure that they are performed at the specified intervals. Normally, scales should be maintained accurate within a tolerance of 0.2 to 0.4 percent of the net load being weighed. Each scale should have at least 10 standard 50 lb. weights meeting the requirements of the National Bureau of Standards for calibrating and testing the weighing equipment. Using these test weights, the scales up to the full amount of the batches. The scale is first balanced at zero load, the weights are added, and the scale reading compared with the actual weight added, and the indicated reading recorded. The weights are then removed, enough material placed in the weighing hopper to produce the same scale setting obtained with the weights, and the weights, re-used to check the scale at higher loads. The scale readings for each increment of weight are recorded and the scale may then be used as a correction factor in batching.

It is recommended that the scale be balanced at zero load at least twice during each shift and checked, and should be inspected frequently for signs of sluggishness, inaccuracy, damage or sticking materials. The scale sensitivity is considered adequate when the beam or dial reacts suitably to the addition of a 5 lb. weight.

Moisture probes and automatic moisture compensation are frequently used in modern batch plants to sense the amount of free moisture in the aggregates and to make compensating adjustments in the amount of water added to the batch. These devices should be checked daily, by comparing against actual moisture tests on the aggregates, to verify proper operation and calibration.

The measurement and addition of water to the concrete batch is a critical quality factor. Most concrete specifi-

cations require that the mixing water be measured within a tolerance of one percent. Water is frequently measured by volume in a calibrated tank, but may be weighed or metered. Whichever device is used should be calibrated by measuring or weighing sample batches drawn out for various control settings. No arrangement of valves or piping should be allowed which could be used to discharge unmeasured water into a mixer that is being charged or discharged. The inspector should observe batching operations frequently and at random to assure that no indiscriminate addition of water to the mixer, for the purpose of increasing the flowability of already workable concrete, occurs.

The addition of admixtures to the concrete batch must also be rigidly controlled, as a small variation in the amount added from the required amount may produce a large variation in the characteristics of the concrete. Admixtures may be measured by weight or volume and added to either the batch or to the mixing water. The dispersing equipment should conform to ASTM C 94 and provide for visual confirmation of the correct volume of each batch and for slow enough discharge so that there is no possibility for an inadvertant double dosage.

Powdered admixtures should be measured by weight, to avoid the fluctuations which usually occur when measurement is by volume. When used in small quantities, powdered admixtures may be weighed and pre-packaged.

The following list summarizes the batch plant operations and equipment that should be inspected to verified by the inspector:

- hopper and chute cleanliness and integrity
- proper valve and closing device operation
- mechanisms intact and operating properly
- weighing equipment properly leveled
- weighing and metering equipment properly calibrated

- moisture compensating equipment calibrated and operating properly
- material proportions calculated and batched accurately, in accordance with specification

## INSPECTION OF CONCRETE MIXING AND TRANSPORTATION

An essential factor in the production of uniform concrete is thorough mixing. The materials must be evenly distributed and all surfaces of the aggregates be well coated with the cement-water paste. To accomplish this effectively in minimum time, the mixer must be properly designed, in good condition, fed efficiently, not overloaded, and operated at the proper speed.

Before the batching and mixing of concrete begins for all major placements, the mixer should be examined to see that the mixing blades and interior of the drum are clean and the blades have not worn more than 10 percent from the original size. The inspector should also verify that the batch timer and counter are operating properly, and that the mixer drum is water-tight.

Stationary and truck mixers are generally equipped with metal plates stating the maximum capacity (volume of mixed concrete), mixing speed, and the gross volume of the drum. For truck-mixed concrete, the volume of mixed concrete should not exceed 63 percent of the total drum volume.

Mixing times vary with the sizes and types of mixer, and are determined by mixer-performance tests then written into the concrete specification. The batch must be mixed for the full specified amount of time to assure thorough mixing. A maximum permissible mixing time is usually established in the specification, and if the batch is to be

delayed longer, the mixer should only be operated at intervals.

Most specifications limit the time the batch may be held before placement. Loss of water, slump and workability occurs with the passage of time. "Retempering", or the addition of extra mixing water, is prohibited. A loss in the strength of the hardened concrete is inevitable if extra water is added. If the concrete is not placed within the specified time or when it is still workable, it must be discarded or used for some other non-structural use.

Air content (entrained air) is also affected significantly by mixing time. Air content is usually increased by about one percent when the mixing time is increased from 1 to 5 minutes. It then remains constant for the next 5 minutes of mixing; but after 10 minutes, air is gradually lost during further mixing. All air may be lost if mixing continues for an hour.

The inspector must also monitor the uniformity of the batches being discharged. If the last portion of a batch being discharged from a mixer contains an excess of coarse aggregate (a segregated condition), the condition should be corrected by adjusting the mixer, the operating conditions, or the size of the batch. The uniformity of a batch may be checked by "washing out" samples of concrete taken from different portions of the batch as discharged; the amount of coarse aggregate in one part should not differ greatly from that in another.

Most concrete is transported from the batch plant to the placement site in truck-mixers. The inspector should check the revolution counter on each truck-mixer to confirm that the number of revolutions at mixing speed is within the specification limits (usually 70 to 100), and that others are only at agitating speed. Periodically, the counters should be checked at random at the batching point to verify

that the counters are zeroed or re-set correctly before mixing and transporting begins.

The following list summarizes the items that should be checked by the inspector during concrete mixing and transportation operations:

- mixer condition, integrity and operating speed
- mixer cleanliness and blade wear
- recommended mixer loading not exceeded
- correct mixing time and speed
- enforce prohibition on "retempering"
- monitor concrete air content, slump and uniformity at discharge point
- monitor mixer revolutions at mixing and agitating speeds

## CONCRETE PLACEMENT INSPECTION

The basic requirement for placing concrete is that the quality of the concrete, in terms of water-cement ratio, slump, air content, and homogeneity must be preserved. The inspector should assure that the proper methods of placing are employed that will prevent segregation and honeycombing, avoid displacement of forms and reinforcement, secure a firm bond between layers, minimize shrinkage cracking, and produce a structure of good appearance. On large projects, such methods are usually detailed in written work procedures which must be followed by all project personnel.

In general, some of the items that should be checked during placement operations are as follows:

- concrete drops should be vertical to avoid segregation.
- concrete should be dropped through pipes or chutes to avoid striking the sides of the forms or reinforcement.

- concrete should be deposited near its final location and not allowed to flow laterally for more than several feet.
- concrete should be placed directly in corners and ends of walls, and not pushed or worked into such areas.
- vibrators should be allowed to operate continuously when being inserted and withdrawn from fresh concrete.
- as a layer of concrete is being placed on a previous layer of fresh, unhardened concrete, revibration of the earlier concrete should be performed by allowing the vibrators to sink as deep into it under their own weight.
- concrete placed on a sloping surface should begin at the bottom and move upward.
- any exposed rocks and segregated aggregate should be shoveled onto softer, plastic concrete areas and thoroughly vibrated.
- spilled concrete should not be shoveled back into buckets and hoppers for subsequent use.
- when concrete is pumped, the inspector should frequently inspect the condition of the concrete being discharged for uniformity and workability.
- concrete lifts should not be placed in depths exceeding the specification requirements.
- inspectors should guard against the addition of water to the concrete batches at all times.
- rejected concrete batches (truck loads, etc.) should be identified and removed from the placement area.
- construction joints should be examined before placement for proper location and configuration.
- expansion joints should be examined before concrete placement for (a) proper joint material, (b) proper

location and alignment, (c) acceptable stability, and (d) freedom from interference with subsequent movement.

- finishing operations should be inspected for conformance to drawing or specification requirements.
- fresh concrete should be covered, if necessary, to protect from inclement weather.
- concrete must be kept moist throughout the curing period.
- forms should be removed as early as possible, and curing procedures implemented and monitored.
- curing procedures should provide for some means of retaining moisture on the concrete, such as wet burlap, cotton mats, wet sand, polyethylene film, or a sprayed sealing compound.
- finished, green concrete must be protected from subsequent damaging construction operations, such as overloading, jarring, surface marring, or heavy impact, that is likely to disrupt the mass or damage the surface.

## EXERCISES

1. Complete the following statements about concrete sampling:
   a. The ASTM Standard for sampling fresh concrete is _____.
   b. The tests on concrete samples taken for slump or air content should be initiated within _____ _____ after sampling.

c. After molding, concrete specimens (cylinders) should not be disturbed for _____.

d. Concrete samples taken from different points in the batch and combined before testing are known as _____.

2. A slump test is performed on the concrete sample as illustrated in Figure A below.

   a. What is the slump of the sample?

   b. What is the tolerance of the slump value?

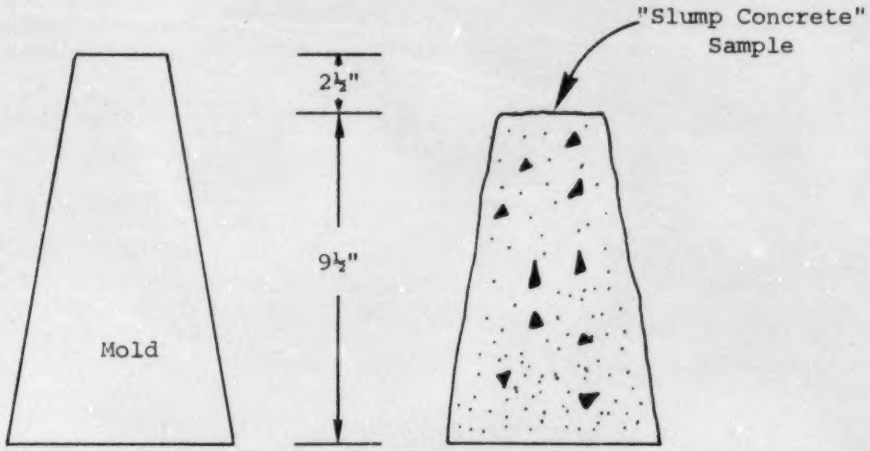



Figure A Slump Test

3. A concrete consistency test is performed as illustrated in Figure B.

   a. What is the name of this test?

   b. What is the indicated penetration depth?

   c. What is the approximate slump value, related to this depth, for normal concrete?

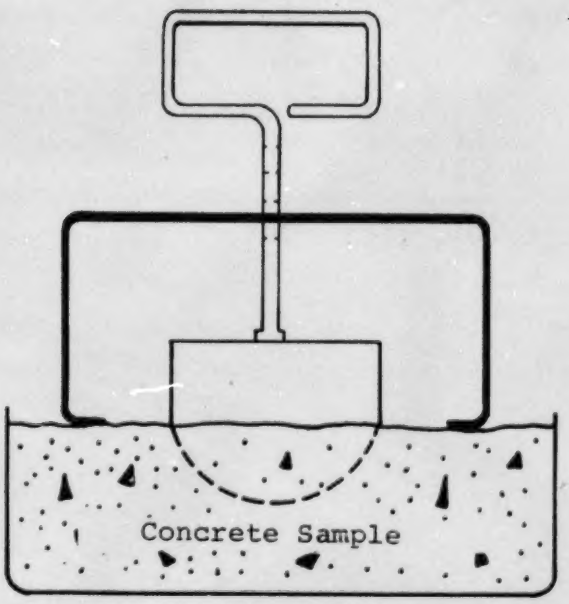



Figure C

4. A sample of concrete is tested with the air content meter shown below in Figure C.
   a. What type meter is it?
   b. What is the apparent air content of the concrete?

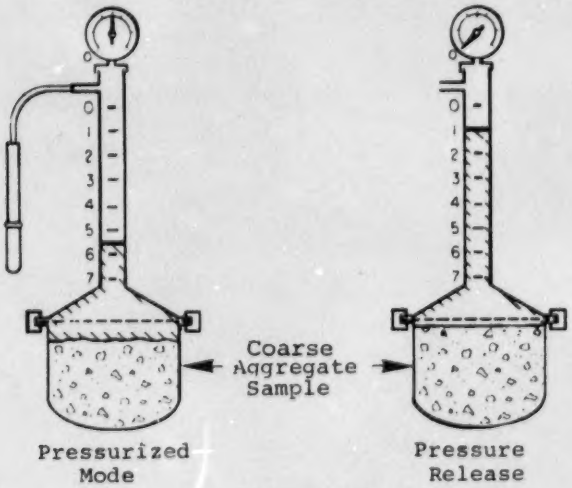



Figure C

A sample of the coarse aggregate is then placed in the meter and tested in the same manner. (See Figure D).

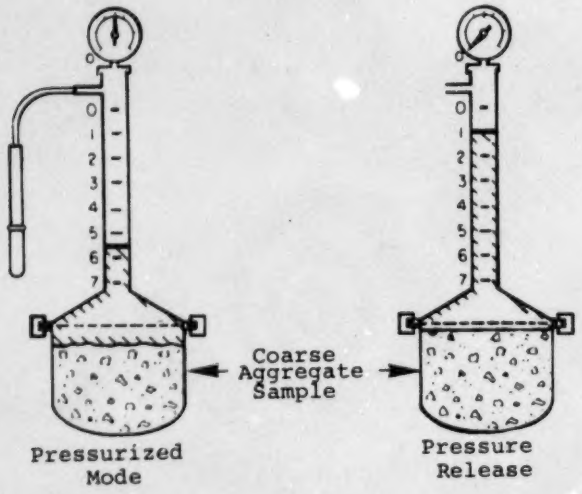



Figure D

c. What is the air content of the coarse aggregate?

d. What is the correction factor to be applied to the apparent air content of the concrete sample?

e. What is the air content (A) of the concrete sample?

5. Molding of compressive strength concrete specimens: indicate on the sketch below, Figure E, how a concrete sample is placed and rodded in a typical cylinder mold: (a)

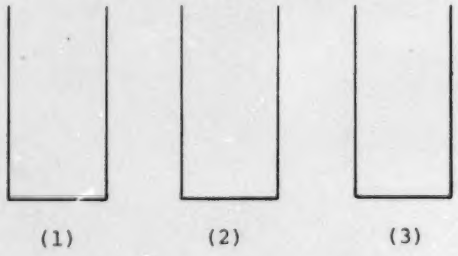



Figure E Molding of Concrete Cylinder

(b) How is the rodding performed?

(c) What is the recommended temperature range for initial curing of the finished cylinders?

6. Concrete was sampled for a large placement, and cylinders were molded for testing as shown in Table 29-5-3. The cylinders were tested, and the maximum load for each recorded in the table.

   a. Calculate the average area and the compressive strength of each cylinder, and enter in the table.

   b. Calculate the mean ($\bar{X}$), standard deviation ($\sigma$), and coefficient of variation (V).

   c. What is the rating of control of the concrete when used for general construction applications?

Table 29-5-3

Cylinder Test Data

| Cylinder | Diameters, Inches | Average Dia. Inches | Area Sq. In. | Max. Test Load, Jbs. | Compressive Strenth, PSI |
|---|---|---|---|---|---|
| 1 | 5.97<br>5.95 | | | 65,800 | |
| 2 | 6.02<br>6.08 | | | 68,120 | |
| 3 | 6.01<br>6.09 | | | 76,760 | |
| 4 | 6.06<br>6.08 | | | 73,510 | |
| 5 | 5.96<br>5.98 | | | 64,100 | |
| 6 | 6.00<br>6.06 | | | 69,400 | |
| 7 | 5.99<br>6.05 | | | 74,280 | |
| 8 | 5.98<br>6.06 | | | 77,410 | |

Calculations: ($\bar{X}$, $\sigma$ & V)

7. The removal of concrete core samples is covered under what standard?

8. How should a cylinder core be sized?

9. Using 10 standard 50 lb. weights, describe the procedure for calibrating a batcher scale for sand up to a capacity of 50,000 lbs.

10. Mark the following statements True of False:
    a. Powdered admixtures should be dispensed into the batch volumetrically. _____
    b. Weighing scales should be sensitive to a 5 lb. increment of material weighed. _____
    c. 300 lbs. of water is required for a specific concrete batch. A 5 lb. deviation from this value is usually acceptable. _____
    d. Standard weights for calibrating concrete batching scales are usually calibrated to ASTM Standards. _____
    e. Automatic aggregate moisture probes and associated equipment should be checked daily for proper operation during concrete batching operations. _____

Perform the following exercises related to inspection of concrete mixing and transportation.

11. Assuming that a mixer is properly designed and in good operating condition, list the operating factors which affect mixing thoroughness.

12. A truck mixer drum is rated at a gross volume of 7.2 cubic yards. What is the recommended maximum volume of mixed concrete that may be mixed in that drum?

13. What are the consequences of "retempering" of mixed concrete?

14. After mixing a batch of concrete for 1 minute, the air content is measured at 3-1/2%. If mixing is continued for another 8 minutes due to an unexpected construction delay, what would the expected air content (in percent) be at that time?

15. How is batch uniformity, with respect to the coarse aggregate, checked at the placement site?

16. Visit a placement site in which concrete is being delivered in rotating drum mixers. Using the Procedures given in this module follow the activities of the inspector and prepare a report on the concrete placement inspection.

## MATERIALS

None.

## PROCEDURES

Visit a site in which concrete is being delivered for placement in rotating drum mixers as indicated in Exercise 16. Follow the activities of the inspector who is performing the concrete placement.

Using the sample check list given in Table 29-5-4 in the Data Table section of this module as a guide, prepare a report on concrete placement inspection.

## DATA TABLE

Table 29-5-4
Concrete Placement Inspection Activities

| Activities of Inspector | Data Complete | Remarks |
|---|---|---|
| 1. Check mixing revolutions and time. | | |
| 2. Sample and test for air content and slump. | | |
| 3. Prepare cylinder specimens for compressive strength tests. | | |
| 4. Check for proper vertical drop of concrete into forms without striking form walls or rebar. | | |
| 5. Check for proper consoldiation (vibration) of concrete in forms. | | |
| 6. Check form integrity and security. | | |
| 7. Check for available weather protection materials. | | |
| 8. Monitor placement activities to preclude the addition of extra mixing water. | | |
| 9. Check form removal, surface repairs, and application of sealing compound within 24 hours. | | |
| 10. Assure that all appropriate records are prepared and completed | | |

# REFERENCE MATERIALS

ACI Manual of Concrete Practice, American Concrete Institute, Detroit, MI

Control of Quality of Ready-Mixed Concrete, National Ready-Mixed Concrete Association, Silver Spring, MD

Sampling and Testing Ready-Mixed Concrete, National Ready-Mixed Concrete Association, Silver Spring, MD

# TEST

A. Answer the following questions as being either True of False.

___ 1. After molding, concrete specimens (cylinders) should not be disturbed for 72 hours.

___ 2. The tests on concrete samples taken for slump or air content should be initiated within one-half hour after sampling.

___ 3. Composite samples are concrete samples taken from different points in the batch and combined before testing.

___ 4. Powdered admixtures should be dispensed into the batch volumetrically.

___ 5. Three hundred and fifty pounds of water is required for a specific concrete batch. A five (5) lb. deviation from this value would be considered acceptable.

___ 6. Standard weights for calibrating concrete batching scales are usually not calibrated to ASTM Standards.

___ 7. Automatic aggregate moisture probes and associated equipment should be checked weekly for proper operation during concrete batching operations.

___ 8. A truck mixer drum rated at a gross volume of 7.2 cubic yards would typically have a recommended maximum volume of about 6 cubic yards of mixed concrete in that drum.

___ 9. Retempering of mixed concrete increases the water - cement ratio, and produces lower strength concrete.

___ 10. Typically, concrete batch uniformity, with respect to the coarse aggregate is checked by washing-out samples taken from the different portions of the 29-5-42 batch, and comparing the aggregates from each.

B. Answer the following essay questions:

1. Using 10 standard 50 lb. weights, describe the procedure for calibrating a batcher scale for sand up to a capacity of 50,000 lbs.
2. Assuming that a mixer is properly designed and in good operating condition, list the operating factors which affect mixing thoroughness.
3. Briefly discuss how a slump test is performed on a concrete sample.
4. A concrete consistency test called the "ball penetration test" is used for testing concrete. Briefly discuss this test and explain how it is performed.
5. Concrete is produced to the specification shown below, and delivered in rotating drum truck mixers to the placement site. The concrete is placed in a 5' deep wall form and should be cured as described below. Compile a brief list of items a concrete placement inspector should inspect, and list the sampling/specimen preparation/testing that should be performed.

Concrete Specification

Compressive Strength: Minimum 3500 psi @ 28 days
Air Content: 3-1/2 $\pm$ 1/2%
Slump: 3 to 5 inches
Mixing: 90 Revolutions, Maximum
8 Minutes, Maximum
Finishing: Form Finish Only, Exposed Aggregate Pockets Removed and Refilled with Grout
Curing: Sprayed Sealing Compound, within 24 hours from Time of Placement